IMPROVEMENTS IN THE DESIGN OF SULFUR BURNERS

BY

EDWARD HUBERT CONROY, JR.

B.S., State University of Iowa, 1942

AN ABSTRACT OF A THESIS

SUBMITTED IN PARTIAL FULFILLMENT OF THE REQUIREMENTS
FOR THE DEGREE OF DOCTOR OF PHILOSOPHY IN CHEMICAL ENGINEERING
IN THE GRADUATE COLLEGE OF THE
UNIVERSITY OF ILLINOIS, 1948

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ACKNOWLEDGMENT

The author wishes to acknowledge his gratitude to Professor H. F. Johnstone, under whose direction this work was done. He is grateful also to the Texas Gulf Sulphur Company which sponsored the Research Assistantship that made this investigation possible. The interest and helpful suggestions of several students and faculty members in Chemical Engineering, and especially the help of Mr. William Loomis with some of the experimental work are also gratefully acknowledged.

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IMPROVEMENTS IN THE DESIGN OF SULFUR BURNERS

Introduction

Sulfur burners in industrial use at the present time are of two types: those in which the liquid sulfur is spread over the interior surface of the combustion chamber in a thin film, and those in which the liquid sulfur is introduced into the combustion chamber as a spray in fine droplets. A search of the literature has disclosed some data on the size and rated capacity of commercial installations, but no method for the design of burners of either type.[1,3,4,6]

A small spray burner has been built and tested in an attempt to discover a relation between the capacity of a burner of this type and its geometry and operating conditions. The chief emphasis has been placed upon a comparison between the observed rate of combustion and the rate of evaporation as calculated from the combustion chamber temperatures and the characteristics of the spray.[2]

Experimental

The spray sulfur burner consisted of an atomizer and a combustion chamber. Several types of atomizers were used before one was found to give complete atomization. The final model consisted of a steam-jacketed venturi tube with a sharply flared divergent section. Sulfur entered through a small tube along the center line of the convergent section and mixed with the air at the venturi throat. The dimensions of this atomizer are given below:

Inside diameter of air line:	1½ inches
Inside diameter of sulfur line:	⅛ inch
Angle of convergence of venturi tube:	30°
Length of venturi throat:	¼ inch

Diameter of venturi throat:	¼ inch
Length of divergent section:	1 inch
Angle of divergence at throat:	10°
Angle of divergence at exit:	60°
Diameter at exit:	¾ inch
Distance from exit of sulfur feed line to upstream end of venturi throat:	0.095 inch
Air temperature:	145°
Sulfur temperature:	145°

The earlier models differed in having a conical divergent section with a seven-degree angle of divergence, and in the method of introducing the sulfur.

The combustion chamber was constructed of fireclay shapes so as to have an inside diameter of five inches and a length of eight feet. It was insulated with 4½ inches of vermiculite insulating brick. Sample ports, and inside and outside wall temperature thermocouples were provided at six points along the length of the combustion chamber.

In order to calculate rates of evaporation, it was necessary to know the sizes of the drops of liquid sulfur produced by the atomizer, particularly the distribution of sizes about the mean. Therefore, the atomizer was first operated without the combustion chamber, and samples of the spray were collected on microscope slides.

In the combustion experiments, the gases in the combustion chamber were analyzed for sulfur dioxide and troxide to determine the point at which combustion became complete.

Results And Conclusions

The results of the atomization experiments may be expressed by the following equations:

A. Throat velocity less than acoustic velocity.

$$D_O = 687(1.5 + W_L/W_A)/(W_A)^{0.90} \quad (1)$$

$$1/q = \tfrac{1}{2} + 1296/(W_A)^{2.0} \quad (2)$$

B. Throat velocity equal to acoustic velocity ($W_A > 55$ lb./hr.).

$$D_0 = 29{,}900(1.5 + W_L/W_A)/(W_A)^{1.63} \quad (3)$$

$$1/q = \tfrac{1}{2} + 94{,}200/(W_A)^{2.82} \quad (4)$$

where D_0 = the diameter in microns of a single spherical drop having the same ratio of surface to volume as the sum of all the drops in the sample.

q = an exponent, which with D_0, specifies the distribution of drops about the mean through the following two equations:

$$dn/dx = ax^2 \exp.(bx^q) \quad (5)$$

$$D_0\, b^q = 5.5/q - 0.5 \quad (6)$$

x = the diameter of an individual drop, in microns.

n = the number of drops in the sample having diameters smaller than x.

W_A = air rate in pounds per hour.

W_L = sulfur rate in pounds per hour.

The results for D_0 average 2.05 times the values predicted from the work of Nukiyama and Tanasawa[5] on atomization of water and organic liquids.

The results of the combustion experiments may be represented by the following table:

Run Number	COMBUSTION CHAMBER VOLUMES (cu.ft./ton S burned/day)		
	Calculated volume required for evaporation (V_C)	Observed volume required for combustion (V_C')	Volume available
60	0.44	0.67	6.0
62	1.01	2.72	6.1
64	0.35	0.47	3.7

It can be seen that the combustion chamber volume required for complete (99.9%) combustion is in each case greater than the calculated volume required for evaporation. The discrepancy is most probably due to neglecting the time required for mixing of sulfur vapor with air after evaporation. A part of the discrepancy may result from the simplifying assumptions used in calculating the rate of evaporation.

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VITA

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